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### COAL-HANDLING DESIGN FOR TVA STEAM PLANTS

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## COAL-HANDLING DESIGN FOR TVA STEAM PLANTS

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### INTRODUCTION

During the last five years the program of the Tennessee Valley Authority has involved the construction of seven large steam plants. All of the plants are coal-fired, and their construction therefore required the design of seven large coal-handling systems. All of the stations are located on a river bank in sections of rural land so that any reasonable amount of space could be utilized for the coal-handling system. As a result, the seven different systems have many features in common, but they are designed for quite a wide range of capacity and, in a number of cases, special features are found at only one or two of the plants.

A design group faced with a program of this extent is subject to mixed emotions. To be engaged on such a large program is always exhilarating. As the plants are at an average distance of only 200 miles from the design headquarters, the designers had opportunity for frequent inspection of their work. However, the speed of the program inevitably produced some regret that possible improvements in design established, for example, by operation of the first system could be introduced initially only into the fourth or fifth system because the speed of the program had already advanced the second, third, and, possibly, fourth plants too far to take full advantage of experiences gained on the first.

Design of a coal-handling system represents the combined effort of civil, mechanical, and electrical engineers, and architects. This paper endeavors to emphasize features of the design which are of particular interest to civil engineers.

### Operating Requirements Affecting Design

The following operating requirements affected the planning of the coal-handling systems:

1. Provision should be made to receive coal by barge, rail, and motor truck whenever these methods were feasible and economical. Actually four stations have barge delivery with future addition of this service possible at two more; six stations have rail delivery with provision for it at the seventh; and two stations have truck delivery with future delivery possible at one additional station.
  2. A coal-storage pile should provide a 90-day supply of coal with coal piled to a height of 25 feet. If more than a 90-day supply is stored, the pile can be built to a greater height.
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3. The coal-handling system in the ultimate station should be assumed to operate about 80 hours per week and should be planned to operate with a minimum amount of manpower consistent with prudent investment.
4. The steam plants have ultimate name plate capacities ranging from 675,000 to 2,250,000 kilowatts. For such large blocks of power, an operating requirement was that there should be two possible ways to deliver coal to the bunkers so that a breakdown at one point could not stop completely the coaling of the station.

#### Basic Design Solutions for Operating Requirements

General solutions for operating requirements were obtained as follows:

1. To coal the ultimate stations in 80 hours per week, capacities of the coal-handling systems were set at from 1200 to 2800 tons per hour.
2. All rail unloading is normally handled by rotary car dumpers. Unloading from barges is accomplished by fixed grab-bucket unloading cranes. Unloading from trucks is accomplished by requiring that all delivery trucks be self-dumping and providing for their dumping on the manual dumping track, normally not needed for rail use, in the car dumper building. Actual and prospective coal purchase contracts were studied to determine the portion of the total coal for each plant that would come from each type of delivery.
3. From the principal unloading points coal is handled by belt conveyors, first to crushers and then either to the bunkers or to a point near the storage pile. Two belts are carried to the bunkers to meet operating requirements for two sources of delivery. However, as the conveyor system spreads into the coal yard, single conveyors become feasible if a conveyor at another point is an alternate source of supply to the bunkers.
4. From the conveyor system to the coal-storage pile and from the pile to reclaiming hoppers coal is handled by automotive equipment, involving tractors and scrapers. The coal pile, the stocking-out conveyors, and the automotive equipment are studied as a unit to develop best operating conditions.
5. Operation with minimum manpower is achieved, in part, by providing a central control room where one operator controls the entire conveyor system. The control room is located at a central elevated point where the operator can observe other operations of the system which are not under his direct control.

#### General Design

The coal-handling operation for steam plants of the size under discussion is a major materials-handling problem. Total costs for these features at projects where status of construction permits knowledge of actual completed cost or is sufficiently advanced for a close estimate have run from \$6,500,000 to \$12,000,000. This represents from 5 to 8 percent of the total cost of the project. A few additional figures can perhaps best illustrate the magnitude of this problem. Kingston Steam Plant, for example, has a name plate capacity of 1,440,000 kilowatts and is scheduled to be completed to its ultimate

capacity late in 1955. The coal-handling system for this station anticipates most of the delivery by rail. The system capacity is 2,000 tons per hour. The coal-storage yard will pile up approximately 1,500,000 tons of coal spread over an area of nearly 60 acres. The coal tracks providing the loaded and empty storage yards in the immediate station area are built in a loop requiring an area nearly 1-1/2 miles long and 1/3 of a mile wide. Storage capacity for 1,800 railroad cars is provided in the interchange, loaded, and empty storage yards at this project. The interchange yard is actually only 4 miles from the loaded storage yard, but 30 miles of track were constructed to provide for all of the rail movement considered necessary. The conveyor system involves over a mile of conveyors despite a layout which favored a minimum of conveyor length. When all coal for operation of the steam plant is being reclaimed from the storage pile, the tractor and scraper equipment must reclaim coal at a rate of approximately 15,000 tons per day. For civil engineers more used to thinking in volume than in weight, this represents an operation of 23,000 cubic yards of coal per day. The round-trip haul will be as much as 3,000 feet. At the Colbert Steam Plant, not yet authorized to its ultimate capacity, most of the delivery of coal is expected to be by barge. To handle the barges there will ultimately be three barge-unloading cranes each with net capacity of 700 tons per hour, and the dock where the barges will be unloaded will be nearly 6,000 feet long. The ultimate station at Gallatin will be even larger and will exceed the figures quoted above for the Kingston Steam Plant by nearly 50 percent.

The first major step in coal-handling design is the basic concept of the location of the necessary features of the system with relationship to the other features in the steam plant layout such as the powerhouse itself, the switchyard, and the condenser circulating water structures. As already noted, the coal-storage yard and the necessary railroad track require large areas; topographic conditions may limit the places where they can be developed. The station layout must provide the necessary space for the coal-storage area in suitable relationship to the other plant features and located to provide proper access for the delivery of coal. In planning these layouts, consideration must be given to the effect of the coal-storage pile on other structures, because of the dust problems always inherent in handling of coal and also of the drainage problem which requires that the corrosive drainage from the coal pile be carried to positions where it cannot damage other structures on the project. These factors will normally require that the coal storage be downstream from the cooling water intake and as far as possible from the main switchyard. It is of course essential, consistent with the broader requirements, that the coal-handling equipment be developed so as to provide minimum lengths of conveyors from the unloading points to the stockpile and to the powerhouse. It is also desirable that the layout permit the crushers to be located close to the unloading points so that run-of-mine coal is handled as little as possible and most of the belts are devoted to the handling of crushed coal.

Figure 1, the general layout of the Shawnee project, illustrates a typical layout. The coal pile is adjacent to the flood plain along the river bank and between the barge-unloading dock and the railroad track loop which provides the loaded and empty car-storage yard. The crusher building is reached by a single belt conveyor from a car dumper and by another from a surge hopper loaded by conveyors from the barge-unloading cranes. Conveyors at right angles handle the coal to the powerhouse in as short a distance as possible or in the opposite direction to the coal-storage yard. The coal-storage pile is

downstream from the powerhouse so that no difficulty is encountered from the drainage and is reasonably far from the powerhouse and switchyard so that dust problems are minimized although prevailing winds do tend to blow the dust toward the powerhouse .

A second example is shown on figure 2 which shows the layout for the Colbert project. Very extensive barge unloading is anticipated, and the ultimate dock will be over a mile long. The site on which the project is built is long and narrow confined between the Tennessee River and Cane Creek. In this particular case, it was possible to place the coal-storage yard upstream from the powerhouse because its drainage is away from the main river and toward Cane Creek which is used for the discharge of the condenser cooling water. In this location prevailing winds blow the coal dust away from the powerhouse. This location also permits the long dock to be close to the coal pile and to provide for crushing of the coal in Bradford breakers between the barge-unloading cranes and the main conveyor run along the coal-storage pile. The long, narrow site requires that the railroad track be beyond the upstream end of the coal pile. This makes this operation at an unusual distance from the main powerhouse, but this arrangement was satisfactory and economical for Colbert because rail unloading is not included in the initial plans and the conveyor system will probably be extended nearly to the railroad yard in order to handle enlarged barge-unloading requirements before railroad facilities are constructed.

#### Detailed Design

##### Barge Unloading

Barge unloading has been provided at four of the seven steam plants. At three, the unloading dock has been constructed by means of steel sheet pile cells either driven into the overburden on the river bottom or set in place on the rock at the river bottom and anchored by tremie concrete. At Johnsonville the dock consists of several reinforced concrete dolphins supported on steel H-piling with intermediate dolphins consisting of bundles of steel H-piling driven into rock. Difficulty has been encountered with damage to these latter pilings, and it has been necessary to strengthen them to resist impact of barges. At all docks each barge-unloading crane is founded on a large cell, flanked by four cells approximately 80 feet on centers to provide a 600-foot-long section of dock where the barges actually being unloaded can be handled. It is anticipated that barges 50 feet wide and 300 feet long may be brought into river service for delivery of coal. To date the largest barges are 50 feet wide and 240 feet long. Beyond this central 600-foot length of dock, at stations with one barge unloader, the dolphins are spaced at intervals of about 175 feet to provide areas for tying up loaded and empty barge fleets. When two or three barge unloaders are used, they are located about 600 to 900 feet on centers with storage areas beyond the unloaders. Special means such as harbor boats then are needed to assist in spotting barges under unloaders and removing them when empty. Dock walkways are provided over the 600 feet of dock used for each barge unloader and for additional distances if the handling problems of unloading seem to require this facility.

All barge-unloading cranes are of the grab-bucket type with net unloading capacity from 450 to 700 tons per hour, equal to a free-digging capacity of 650 to 1000 tons per hour. The largest buckets used have been a 9-ton capacity as this is approximately the largest physical size which can be used satisfactorily in 26-foot-wide barges--the smallest received. The bucket cycle



usually ranges from 30 to 35 seconds. Barge unloaders are operated either by variable-voltage direct-current equipment or by alternating-current equipment, with preference for the former. Structural framework for the barge unloaders has been varied. For Widows Creek a hammerhead crane used to place concrete in Fontana Dam was rebuilt for unloading coal. At the Shawnee Steam Plant unloaders are diagonally braced structures typical of those found in river operations. However, figure 3 is a photograph of the barge unloader at Johnsonville Steam Plant, to be duplicated by two unloaders at Colbert Steam Plant, and represents our idea of a more suitable structural arrangement for this equipment. Its all-welded rigid frame design is far more suited to fitting into the basic concept of appearance of the modern steam plant. However, entirely aside from appearance, this type of design has been found to be actually more economical than the standard designs. The economy of its fabrication has often been questioned by both our own engineers and the crane builders, but after the builder has actually fabricated one of these unloaders he has bid them in preference to the standard kind as he has found them cheaper in his own shop. The Authority has erected all of its unloaders with its forces and has found that the erection of this unloader was faster and cheaper than was the erection of other types. Its large, clean surfaces will also permit economies in maintenance.

#### Rail Unloading

Each of the plants is within reasonable distance of a major railroad. In general, delivery of coal by rail has involved the construction of an interchange yard at the main rail line and loaded and empty storage yards at the project. These latter yards have normally been in the form of a loop with the car dumper a part of this loop between the two yards. At one plant, John Sevier, it was necessary to relocate the main line railroad track in order to develop a large enough site area. In this case, rail delivery is accomplished by a straight-line track arrangement paralleling the main rail line and without need for an interchange yard. The capacities of the three yards on the typical plant vary, depending upon the delivery conditions. Where the main line is nearby, the interchange yard can be small and cars move immediately to the steam plant yard where a 3-day storage is supplied in the loaded yard and 2-1/2 day storage in the empty yard. Where the main railroad is at some distance and where more than one railroad may be involved, a typical design has provided 4-1/2-day storage in the interchange yard and 1-1/2-day storage in each the loaded and empty storage yards. The cars are brought in to the loaded storage yard by the Authority's own locomotives. For long hauls, these are 120-ton-capacity, Diesel-electric locomotives. In the plant yard, 80-ton, Diesel-electric locomotives handle the cars in all the operations. The principal operation is handling cars from the loaded storage yard through the car dumper. When each car is discharged from the car dumper, it runs over a short, relatively steep grade, which together with small additional drop to the empty yard, permits placing the car in the empty storage yard without use of locomotive. However, in order to effect the most satisfactory operation under varying car and weather conditions, car retarder units which will automatically release the cars at the proper speed to ensure their proper travel to the empty storage yard are being installed.

#### Truck Unloading

Coal mines are sufficiently near to permit truck deliveries to two stations initially and possibly one more in the future. For such cases a 50-ton scale

is provided for weighing the incoming trucks. The platform on this scale is 50 feet long. This is necessary for the large trailer units which are used. It is required that trucks delivering coal have automatic dump bodies and, after weighing, they are driven over the hopper into which the car dumpers also discharge in order to deliver their load.

#### Belt Conveyors

The conveyors and their associated equipment and controls are probably the key point of the coal-handling system. However, the design of this equipment is more particularly the field of the mechanical and electrical engineers, and for that reason will receive less than its proper proportional share of this paper.

Conveyors and their associated equipment are designed carefully by the Division of Design of the Authority. The design drawings and accompanying specification are then issued for bids for purchase of the necessary equipment. The completeness of the design drawings has developed excellent relations with the conveyor manufacturers and has resulted in very satisfactory bids. On the most recent procurement, for example, nine bids on conveyor equipment were submitted, and the low seven were within a cost range of 8 percent.

Belt conveyors are of customary type, operating on troughing idlers. Belt widths range from 42 to 60 inches to carry from 600 to 1400 tons of coal per hour. Belt speeds are continually being increased, and current designs plan belt operation at maximums of 500 to 550 feet per minute. This speed, however, must be reduced on belts where primary tramp iron separation is provided, as the design of magnetic separating equipment does not yet permit maximum belt speeds if proper separation is to be obtained. The loading of coal onto the belts is in all cases accomplished by means of vibrating feeders. Almost all coal received is run-of-mine, and it must be crushed to 1-1/4-inch maximum size before being placed in the bunkers prior to further preparation by the pulverizers. At the earlier stations crushing was accomplished by ring-type crushers but for later designs Bradford breakers with hammermill attachments have been provided. The latter equipment is more expensive but is believed justified on the basis of lower crushing costs; however, actual operations have not yet been begun which will provide operating data on this subject.

Conveyor belts which carry coal to the storage area for further handling by automotive equipment have been developed on several bases. On the earlier plants, these conveyors were in fixed positions so that coal discharging from them formed a conical pile on the ground. For the rate at which coal was being handled, this conical pile tended to build up too rapidly for most effective handling by automotive equipment. At the Colbert station, therefore, the stocking-out conveyors oscillate so as to discharge the coal into a windrow. Further refinement of this design is being provided at the John Sevier and Gallatin plants where the stocking-out conveyor will oscillate and discharge through a rotating spout so that coal will blanket the ground over an area of approximately 120 by 50 feet.

For reclaiming coal to the conveyor system, large reclaim hoppers are provided, covered with heavy grating at ground level. Automotive equipment runs over this grating to dump its load. For plants where reclaim capacity of a hopper is about 700 tons per hour, the reclaim hoppers are about 18



feet wide and 33 to 49 feet long. These dimensions require that automotive equipment stop to dump its load but are sufficiently large so that spotting of the load is simple. At John Sevier and Gallatin where the reclaim hopper is rated at 1400 tons per hour, the width of the grating is doubled to 36 feet to provide two lanes of operation for the automotive equipment.

#### Stockpile Operations

Handling of coal into and out of the stockpiles is a large materials movement. As already noted, the largest plant now under construction will require that coal be reclaimed at a rate of 23,000 cubic yards per day with round-trip haul of 3,000 feet, and the Gallatin plant as ultimately conceived will require a rate of 35,000 cubic yards per day. Equipment best-suited for this work is considered to be the rubber-tired tractor and scraper. Quantities are such that the largest possible equipment seems desirable, and scrapers of 22-yard struck capacity are used for most of this work. In order to minimize manpower required for coal operations, specifications for tractive equipment have required that the tractor self-load the scrapers, thus eliminating the additional manpower necessary if push-loaded scrapers were used. In initial purchases the development of rubber-tired equipment was not yet sufficiently advanced to permit purchases in accordance with this requirement, and crawler-type tractors were purchased. Now, however, at least two manufacturers are able to supply rubber-tired equipment capable of self-loading in reasonable distances either in loose or compacted coal, and the crawler equipment is being distributed to the seven steam plants for use in bulldozer operations, and rubber-tired equipment is being procured for all hauling operations.

#### Coal-handling Structures

Structures required by the coal-handling systems are the conveyor supports, the hopper building where the car dumper is located, crusher building, utility building, and possibly special buildings for conveyor control and dock service.

To date all coal-handling designs have provided complete enclosure for all of the conveyors. Where the conveyor is underground, this has been developed by simple rectangular cast-in-place concrete tunnel sections built by cut and cover methods. For structures above the ground, conveyors have been carried in the customary fashion in riveted truss structures with deep maroon-colored Galbestos siding, black Galbestos roofing and floors of precast concrete slab. This type of enclosure is not, however, considered to be a standard automatically accepted for all projects. For the Gallatin project, a number of special conditions exist which has resulted in current investigation of the desirability of replacing the enclosed truss structure by beam or girder structures with a superimposed cover. It appears that this alternate will be quite comparable to the truss-type structure, but final decision has not yet been made. On all stations, consideration has been given to permitting the conveyor structures above ground to be in the open except for covers locally above the belt and over drive machinery. Thus far, however, final designs have concluded that the slight extra cost for conveyor enclosure has been justified.

The hopper buildings are standard types of structures used for installation of car dumpers. Below ground, these buildings are reinforced concrete foundations for the dumper and superstructure but built to provide for the coal hoppers and for room below these hoppers for the feeders loading coal to the belt. At the earlier stations a hopper building superstructure enclosed the car

dumper operation and provided small rooms for tools, electrical equipment, dumper controls, and use of dumper crew in winter weather. On the designs for the John Sevier and Gallatin stations the superstructure over the car dumper has been eliminated and only the small rooms provided. Provision has been made to provide a superstructure over the dumper if this open-type operation is found unsatisfactory.

Crusher buildings at the stations using ring-type crushers are simple structures enclosing this equipment and planned so that the crushers are located at or a short distance above ground level. At the top of this building a control room with large areas of glass wall has been developed in a way to give the operator clear view over many of the coal-handling operations. A single-story annex to this building provides enclosure for electrical equipment necessary for the conveyor system.

At the stations where Bradford breakers are used for crushing operation, the breakers are supported a short distance above the ground by a steel frame. The breaker itself is left as much as possible in the open. This sort of crusher structure does not permit a conveyor control room such as used on the other projects, and therefore a separate building designated as conveyor control building has been provided. On the lower floor of these structures, space is provided for electrical equipment and possibly for locker rooms for employees. On the upper floor is provided the central control in a glassed-in-area.

Utility building structures are single-story buildings providing relatively large areas for maintenance of the automotive equipment and of the Diesel-electric locomotives used in the coal-handling operation. In a few cases, these buildings have also provided a small amount of storage space.

At two projects a small dock service building was necessary to provide lockers, tool, and office space for dock personnel. These structures harmonized with other coal-handling structures.

Hopper, crusher, utility, conveyor control, and dock service buildings all have structural steel frames with walls of brick, glass, and aluminum or Galbestos siding. Transfer structures required in the conveyor system also use aluminum or Galbestos siding.

All structures in the coal-handling system have been located to provide best possible operating conditions. Although the structures are in no way unique, the same careful attention has been given to all details of their design as has been given to the main powerhouse structure. As a result, the coal-handling systems at these stations have an appearance fully suited to their important function in these large steam stations. This is illustrated by figure 4 which is a photograph of a major portion of the coal-handling system at the Johnsonville Steam Plant.

#### ACKNOWLEDGMENTS

All engineering and construction work for TVA is under the direction of C. E. Blee, M. ASCE, Chief Engineer. R. A. Monroe, M. ASCE, Chief Design Engineer, is in charge of the Division of Design.

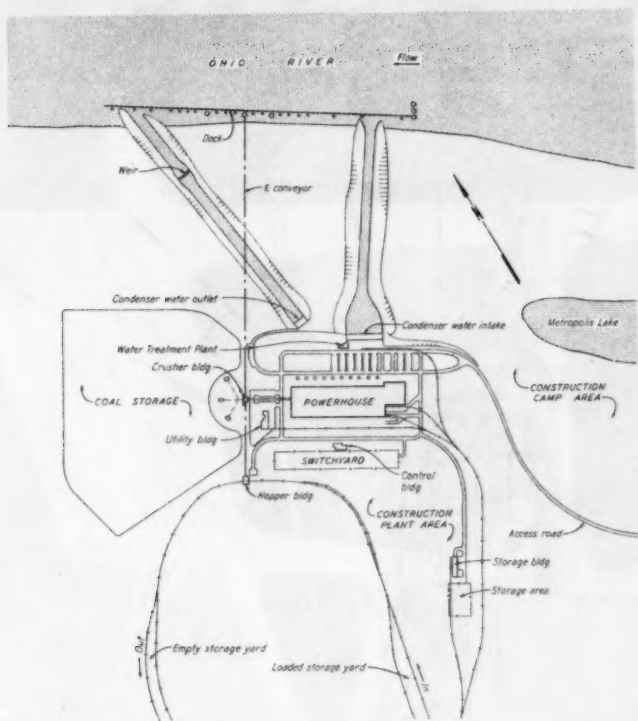


Figure 1

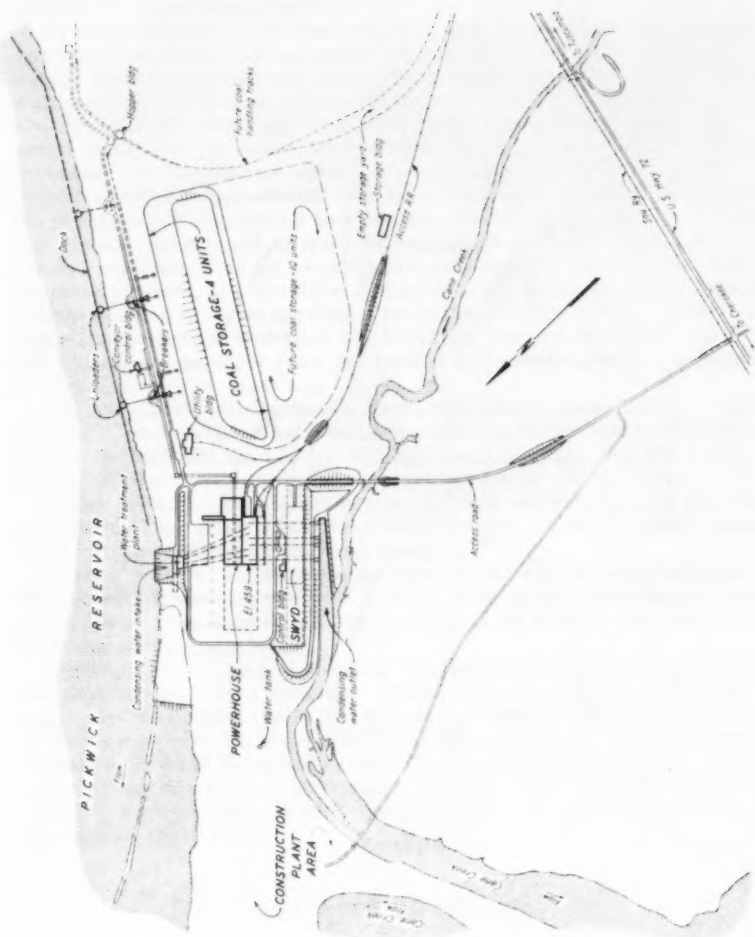


Figure 2

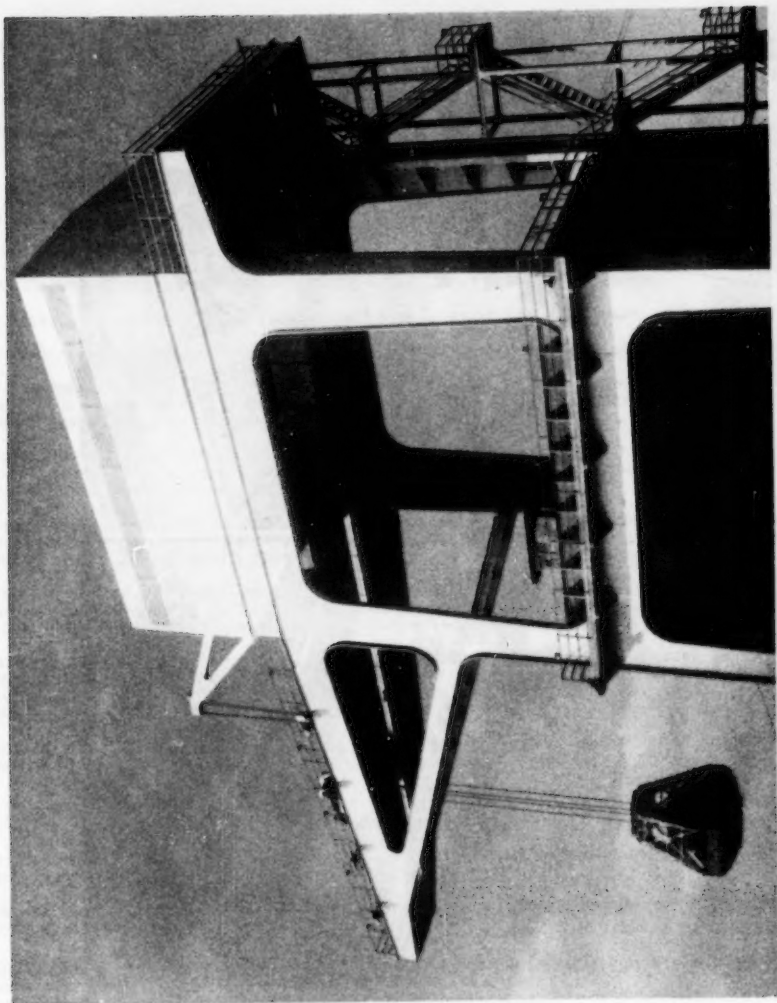


Figure 3

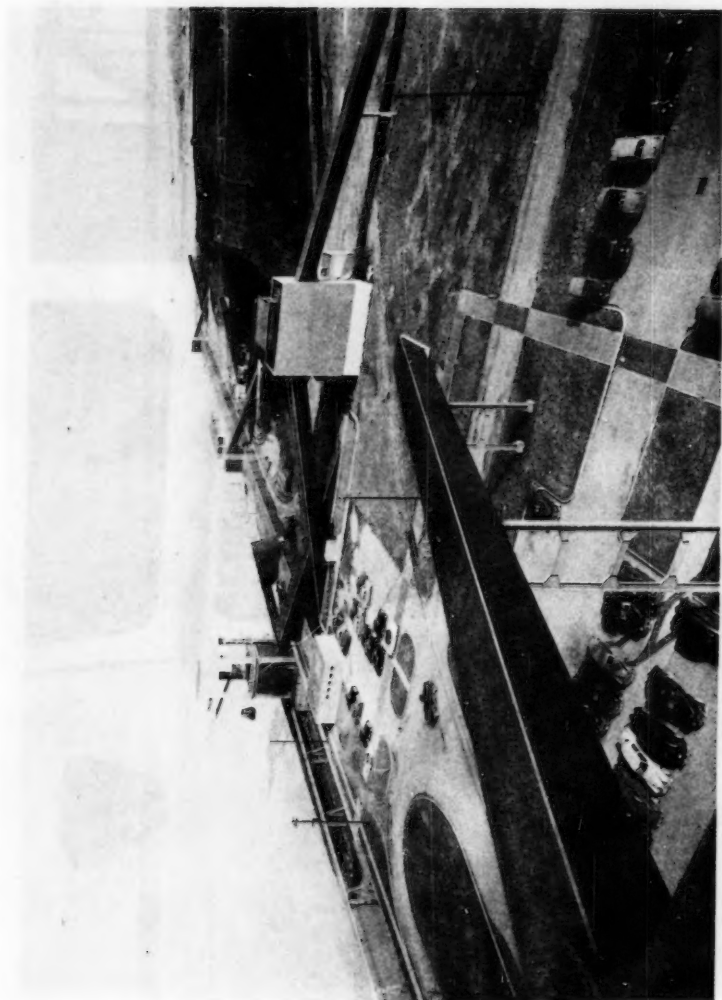


Figure 4



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## VOLUME 79 (1953)

FEBRUARY: 169(HY), 170(ST), 171(CP), 172(SU) & (AT), 173(SU) & (AT), 174(SU) & (AT), 175(HY), D-121(HW), D-127(ST).

MARCH: 176(SA), 177(EM), 178(HY), 179(EM), 180(HY), D-123(HY), D-126(ST), D-128(ST).

APRIL: 181(WW), 182(ST), 184(HY), 185(EM), 186(HY), 187(ST), 188(HY), D-135(HY), D-136(ST).

MAY: 189(HY), 190(HY), 191(CP) & (AT), 192(SM), 193(HY), D-129(PO), D-138(CP), D-145(ST).

JUNE: 194(CP) & (AT), 195(SM), 196(CP) & (AT), 197(HY), 198(ST), 199(EM), D-134(HY), D-141(HY).

JULY: <sup>a</sup> 200(SM)<sup>b</sup>, 201(ST)<sup>b</sup>, 202(EM)<sup>b</sup>, 203(SM)<sup>b</sup>, 204(AT)<sup>b</sup>, 205(EM)<sup>b</sup>, 206(ST)<sup>b</sup>, 207(SA)<sup>b</sup>, 208(SA)<sup>b</sup>, 209(ST)<sup>b</sup>, 210(SU)<sup>b</sup>, 211(EM)<sup>b</sup>, 212(SU)<sup>b</sup>, 213(IR)<sup>b</sup>, 214(HW)<sup>b</sup>, 215(SM)<sup>b</sup>, 216(ST)<sup>b</sup>, 217(ST)<sup>b</sup>, 218(ST)<sup>b</sup>, 219(ST)<sup>b</sup>, 220(SM)<sup>b</sup>, 221(HW)<sup>b</sup>, 222(SM)<sup>b</sup>, 223(EM)<sup>b</sup>, 224(EM)<sup>b</sup>, 225(EM)<sup>b</sup>, 226(CO)<sup>b</sup>, 227(SM)<sup>b</sup>, 228(SM)<sup>b</sup>, 229(IR)<sup>b</sup>.

AUGUST: 230(HY), 231(SA), 232(SA), 233(AT), 234(HW), 235(HW), 237(AT), 238(WW), 239(SA), 240(IR), 241(AT), 242(IR), 243(ST), 244(ST), 245(ST), 246(ST), 247(SA), 248(SA), 249(ST), 250(EM)<sup>c</sup>, 251(ST), 252(SA), 253(AT), 254(HY), 255(AT), 256(ST), 257(SA), 258(EM), 259(WW).

SEPTEMBER: 260(AT), 261(EM), 262(SM), 263(ST), 264(WW), 265(ST), 266(ST), 267(SA), 268(CO), 269(CO), 270(CO), 271(SU), 272(SA), 273(PO), 274(HY), 275(WW), 276(HW), 277(SU), 278(SU), 279(SA), 280(IR), 281(EM), 282(SU), 283(SA), 284(SU), 285(CP), 286(EM), 287(EM), 288(SA), 289(CO).

OCTOBER: <sup>d</sup> 290(all Divs), 291(ST)<sup>c</sup>, 292(EM)<sup>c</sup>, 293(ST)<sup>c</sup>, 294(PO)<sup>c</sup>, 295(HY)<sup>c</sup>, 296(EM)<sup>c</sup>, 297(HY)<sup>c</sup>, 298(ST)<sup>c</sup>, 299(EM)<sup>c</sup>, 300(EM)<sup>c</sup>, 301(SA)<sup>c</sup>, 302(SA)<sup>c</sup>, 303(SA)<sup>c</sup>, 304(CO)<sup>c</sup>, 305(SU)<sup>c</sup>, 306(ST)<sup>c</sup>, 307(SA)<sup>c</sup>, 308(PO)<sup>c</sup>, 309(SA)<sup>c</sup>, 310(SA)<sup>c</sup>, 311(SM)<sup>c</sup>, 312(SA)<sup>c</sup>, 313(ST)<sup>c</sup>, 314(SA)<sup>c</sup>, 315(SM)<sup>c</sup>, 316(AT), 317(AT), 318(WW), 319(IR), 320(HW).

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JANUARY: 379(SM)<sup>e</sup>, 380(HY), 381(HY), 382(HY), 383(HY), 384(HY)<sup>e</sup>, 385(SM), 386(SM), 387(EM), 388(SA), 389(SU)<sup>e</sup>, 390(HY), 391(IR)<sup>e</sup>, 392(SA), 393(SU), 394(AT), 395(SA)<sup>e</sup>, 396(EM)<sup>e</sup>, 397(ST)<sup>e</sup>.

FEBRUARY: 398(IR)<sup>f</sup>, 399(SA)<sup>f</sup>, 400(CO)<sup>f</sup>, 401(SM)<sup>f</sup>, 402(AT)<sup>f</sup>, 403(AT)<sup>f</sup>, 404(IR)<sup>f</sup>, 405(PO)<sup>f</sup>, 406(AT)<sup>f</sup>, 407(SU)<sup>f</sup>, 408(SU)<sup>f</sup>, 409(WW)<sup>f</sup>, 410(AT)<sup>f</sup>, 411(SA)<sup>f</sup>, 412(PO)<sup>f</sup>, 413(HY)<sup>f</sup>.

a. Beginning with "Proceedings-Separate No. 200," published in July, 1953, the papers were printed by the photo-offset method.

b. Presented at the Miami Beach (Fla.) Convention of the Society in June, 1953.

c. Presented at the New York (N.Y.) Convention of the Society in October, 1953.

d. Beginning with "Proceedings-Separate No. 290," published in October, 1953, an automatic distribution of papers was inaugurated, as outlined in "Civil Engineering," June, 1953, page 66.

e. Discussion of several papers, grouped by divisions.

f. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.

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